

CPUC Energy Storage Use Case Analysis

Distribution Energy Storage: Distributed Storage Peaker

Authors:

Mark Hardin, Director Product Marketing, 512-286.3949 x4224

MHardin@xtremepower.com

Amanda Brown, Vice President, Policy & Regulatory Affairs, 512.268.3949 x4409,

ABrown@xtremepower.com

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1. Overview Section

Although energy storage systems can be built at the transmission, multi-megawatt scale to provide bulk energy storage applications, smaller, distributed energy storage systems (DESS) placed on the distribution circuits offer several specific advantages that cannot be met with large bulk storage products or more traditional industry solutions.

DESS units can be sited locally with minimum permitting as installations do not require a gas line, water for cooling, or additional transmission lines and significant operation noise. This ability to be sited at a substation or closer to load can help improve service reliability by discharging to serve the load of a specific distribution substation for multiple hours. This provides utilities a defined window of time to fix an outage at a substation without their customers seeing any power interruption or loss of service.

Also, energy storage systems may be able to help resolve issues rising from deeper penetration of customer-owned solar photovoltaic (PV) systems, which is being advanced via several state policies including the California Solar Initiative, Utility-Side (Wholesale) Distributed Generation Programs, and Governor Brown's Clean Energy Plan. Energy storage located on distribution feeders exhibiting high penetration of such distributed resources can provide substantial reliability benefits and cost savings compared to upgrading distribution circuits and equipment, thus helping achieve the levels of PV and DG penetration targeted in the existing state policy.

Additionally, storage at the Distribution level can help solve local voltage and reactive power problems that can occur at the substation and thus improve the stability and efficiency of the distribution equipment for the utility. Distinct advantages are derived from the ability to be sited and sized for location specific challenges. Within the general category of Distribution-level energy storage, there are three applications of specific interest: Distributed Storage Peaker, Energy Storage for Distribution Grid Operations, and Community Energy Storage.

2. Use Case Description

This Use Case describes a network of individual Distributed Energy Storage Systems (DESS), each with capacities ranging from 20 kW up to a few MW, which in aggregate provides tens of megawatts of capacity for a duration of 2-4 hours. This energy storage solution would function effectively to address local substation specific problems, provide peaking capacity, and deliver ancillary services by connecting to and charging off the distribution system..

It is assumed that the resource has successfully connected to the distribution grid under California ISO interconnection rules and processes and includes CAISO-approved telemetry that allows for remote monitoring of the resource and related factors.

2.1 Objectives

Although the challenges and needs of distribution system is similar to those of the larger, system wide transmission system, the distribution problems are location-dependent and thus are best solved at the local level. Networked DESS offers a solution that can both help solve local distribution level needs and provide a coordinated response to alleviate system level peak load.

Located at the distribution level or further downstream, the primary objective of a DESS would be to participate in wholesale markets by offering dispatchable capacity and energy to meet operational needs during peak demand hours. Secondary objectives include the potential to reduce emissions and provide ancillary services for balancing and reliability. These applications in addition to the localized benefits could help DESS a more economically viable option for utilities today.

In comparison to conventional, gas-fired peaking plants (“peakers”), a storage peaker may offer several advantages, including: more operational flexibility, emissions reduction, renewable integration, procurement flexibility, modular sizing, and faster installation.

2.2 Actors

In this Use Case, if the DESS is located within a substation it will be owned by a utility which could be defined as a distribution service provider, cooperative, municipality, or fully vertically integrated utility. If the DESS is located outside of a substation or behind the meter, other third party owner/operators could become involved. However, additional actors or market participants may be required for system design, installation, and operation as outlined in the table below.

<i>Name</i>	<i>Role description</i>
<i>Storage Equipment Provider</i>	The provider of component(s) necessary to build an operational facility. This could be a single or multiple parties acting together.
<i>Storage Developer</i>	The developer manages or performs permitting, financing, and construction of a site to create a complete project.
<i>Storage Owner/ Operator</i>	Owns, operates, and maintains resource.
<i>Utility</i>	A load serving entity that procures capacity and energy to serve its retail customers. The utility pays the CAISO for ancillary services based on a percentage of its load. The utility may meet its capacity and energy requirements through long-term contracts.
<i>Grid Operator</i>	This document assumes that the grid operator is the CAISO. The CAISO operates the energy and ancillary services markets and

	dispatches generators. The CAISO procures ancillary services.
<i>Scheduling Coordinator</i>	The entity that schedules or bids an asset into the CAISO markets. This could be the owner, utility with a contract, or a third party.
<i>On-Site Resource Owner</i>	Generally same as the storage owner or a joint partnership with storage provider.

2.3 Proceedings and Rules that Govern Procurement and Markets

	<i>Description</i>	<i>Applies to</i>
CPUC	General Order 85- Overhead	
CPUC	Long-term Procurement Proceeding	Utility
CPUC	Resource Adequacy	Utility
CPUC	Energy Storage OIR - R.10-12-007	Utility
CPUC	Rule 2- Rules of Service	Utility
CPUC	Rule 21- Interconnection	Utility
CAISO	GIP (Generator Interconnection Procedure)	Project developer/owner
IEEE	IEEE1547	Utility

2.4 Location

The individual DESS units are connected to the distribution grid and can be located at a substation or even further downstream next to residential level transformers for the smaller (< 100 kW) capacity systems or behind the meter. The substation sited DESS would be owned and operated by the local utility, while the DESS located outside the substation or behind the meter would be owned by a non-utility third party. The DESS would charge and discharge from the distribution grid directly. Multiple DESS can be aggregated into a local controller and multiple local controllers can be aggregated into a single master controller. This tiered distributed control architecture enables the owner/operator to command an integrated response and monitor performance of an entire fleet of DESS located throughout a service area all from a remote operation center.

2.5 Operational Requirements

DESS capacity can range from 20 kW per module for residential level systems and up to a few MW for substation level systems. In order to provide peak shaving and time shifting, DESS must have 2 to 4 hours of duration at rated capacity per module. Minimal footprint, easy installation, and low maintenance are all design features that should be optimized to make implementation and operation as cost effective and simple as possible for the operator.

From a software and control perspective, DESS must be able to perform multiple applications including power factor correction, voltage support, frequency response, automatic peak shaving, scheduled time shifting, AGC response, and market based dispatch services. Furthermore, DESS control must be available both at the local individual module level and at an aggregated service area wide level. This drastically increases operational flexibility by offering solutions for local constraints by controlling individual DESS modules and system level challenges by commanding a coordinated response to provide capacity on demand to reduce peak load similar to a bulk storage peaker. In addition to the energy storage system itself, there are other key systems and components required to operate a distributed storage asset on the grid as outlined in the table below.

<i>System</i>	<i>System description</i>
<i>Energy Storage System</i>	These are devices that can quickly store or discharge energy for grid operation and control such as batteries, flywheels, compressed air energy storage and aggregated plug-in electric vehicles.
<i>Distribution Management System</i>	Application(s) use by the storage provider to monitor, control, and optimize the performance of the distribution system.
<i>Distributed Energy Resource Management System (DERMS)</i>	DERMS is an advance software application that optimizes resource utilization in response to system operational events, environmental and equipment conditions, and market conditions. DERMS includes several different, but integrated, software components that incorporate advanced optimization algorithms to dispatch demand and supply side resources.
<i>Measurement Device</i>	If providing power quality services, this will be needed to measure voltage or other power quality indicators that would provide information about the condition of the distribution system

DESS controls and communications are a critical system component required to enable multiple services and remotely command individual modules or a system wide network of DESS. Depending on the applications the DESS is expected to provide, the control system must read multiple inputs from various

measurement devices in order to respond appropriately. Additionally, the control system must take readings from internal DESS components such as the Battery Management System (BMS) and environmental control systems. All system level communications should use a protocol common in other industry equipment SCADA such as Modbus or DNP3. Typical measurement inputs required include but are not limited to:

<i>Measurement/Input</i>	<i>Purpose/Use</i>
<i>Grid Voltage and Current</i>	Calculate frequency and power at point of interconnection; respond to grid events (frequency response, voltage support)
<i>Automatic Generation Control</i>	Respond to dispatch signals sent by the ISO for market based services
<i>Real/Reactive Power Commands</i>	Respond to commanded/scheduled charges/discharges from the owner operator/master controller
<i>Breaker/Switch Gear Status</i>	Immediately enter a protective shutdown or idle mode if breaker opens
<i>BMS Readings</i>	Monitor state of charge, battery temperature, battery health, DC current, etc.
<i>PCS Readings</i>	Monitor MVA inputs/outputs of the Power Conversion System (PCS)
<i>Environmental System Readings</i>	Monitor ambient air, coolant temperatures, fan/pump loadings and pressures to maintain required operational conditions
<i>Various Alarms/Fault Readings</i>	Warn owner operator of system conditions or shutdown if required

2.6 Applicable Storage Technologies

The operational requirements combined with space limitations for likely siting lends battery based storage as the most appropriate technology for DESS. Depending on the expected operational requirements of a specific DESS installation, several battery chemistries could be utilized in the design including various lithium ion chemistries, advanced lead acid, sodium nickel chloride, sodium sulfur and flow battery chemistries.

<i>Storage Type</i>	<i>Storage capacity</i>	<i>Discharge Characteristics</i>
Battery: Lithium-ion	Durations of 30 mins-4 hours	High power discharge and able to operate efficiently at a partial state of charge
Battery: Advanced Lead Acid	Durations of 5 mins-4 hours	High power discharge and able to operate efficiently at a high state of charge
Battery: Sodium Nickel Chloride	Durations of 2 -4 hours	Ideal is deep cycle discharge and able to operate efficiently at a partial state of charge
Battery: Sodium Sulfur	Durations up to 6 hours	High power discharge and able to operate efficiently at a high state of charge
Battery: Redox Flow Batteries	Duration of 4-6 hours duration	Able to operate at all states of charge

2.7 Non-Storage Options for Addressing this Objective

Of the non-storage alternatives available today, none of them offer the same range of diverse solutions from a single resource. Utilities have many existing options to solve problems related to growing demand, overloaded distribution circuits, and voltage stability concerns including:

- Fuel cell technology to provide on peak energy in a distributed format
- Upgrading distribution level equipment such as transformers, switchgear, and electrical lines to increase the available capacity of the distribution network
- Capacitor banks and static VAR compensators to aid in power factor and voltage stability
- Automatic demand response programs to reduce peak load
- Procurement of additional energy from the ISO during peak demand periods

3. Cost-Effectiveness Analysis

3.1 End Uses / Benefits

<i>End Use</i>	<i>Primary/Secondary</i>	<i>Benefits/Comments</i>
1. Frequency regulation	S	Earn revenues in Fast Acting Regulation market.
2. Spin	S	If it can qualify.

End Use	Primary/ Secondary	Benefits/Comments
3. Ramp	S	Adds flexible supply capacity in milliseconds at nameplate.
4. Black start	S	
5. Real-time energy balancing	S	Discharge energy in the real-time energy markets.
6. Energy arbitrage	S	Earn revenues from discharging during periods of peak demand and charging when prices are low.
7. Resource Adequacy	S	If it can provide on a firm basis.
8. VER ¹ / wind ramp/volt support,	S	
9. VER/ PV shifting, Voltage sag, rapid demand support	S	
10. Supply firming	S	
11. Peak shaving: load shift	P	Automatically discharge energy when local distribution lines reach capacity to reduce peak load
12. Transmission peak capacity support (deferral)	N/A	
13. Transmission operation (short duration performance, inertia, system reliability)	N/A	
14. Transmission congestion relief	N/A	
15. Distribution peak capacity support (deferral)	P	Defer expensive distribution infrastructure upgrades by increasing efficiency and reducing peak demand of distribution system.
16. Distribution operation (volt/VAR support)	S	Instantly improve local power quality by providing reactive power and responding to voltage fluctuations.

¹ VER = Variable Energy Resource

<i>End Use</i>	<i>Primary/ Secondary</i>	<i>Benefits/Comments</i>
17. Outage mitigation: micro-grid	S	They are currently doing this now on a micro-grid.
18. TOU energy mgt	S	Ex. Non-utility owned: peak shaving for Industrial /Commercial customers to manage demand charges.
19. Power quality	S	Inject or absorb real or reactive power instantly and accurately to help with local power quality issues.
20. Back-up power	S	Immediately discharge to continue supplying energy to loads in the event of an outage.

3.2 Other Beneficial Attributes

Along with the applications outlined in the table above, a DESS acting as a distributed peaker provides unprecedented flexibility in its design, procurement, installation, and operation. An outline of these beneficial attributes is provided in the table below.

<i>Attribute</i>	<i>Benefits/Comments</i>
Modularity/Incremental build	Improve system upgrade efficiencies by purchasing only the capacity needed.
Faster build time	Reduce project logistics and project financing costs.
Locational flexibility / Mobility	Site systems at source of grid challenge; re-deploy if new challenge arises at different site or current site challenge is no longer an issue to enable continued distribution upgrade deferrals.
Multi-site aggregation	Command transmission level capacity (multi-MW) from network of smaller distributed and locally sited systems.
Operational Optionality	Solve multiple grid challenges with one solution; Update system software to add services or adapt algorithms to meet evolving grid challenges.

3.3 Costs

The costs of Distributed Energy Storage Systems vary widely as a function of duration, type of storage technology employed, and operational duty cycle. Longer duration systems require more energy storage while keeping the capacity rating (kW) constant which effectively increases the normalized \$/kW

installation cost of a system. Maintenance costs are generally fairly immaterial, but can increase with low efficiencies or if the DESS design requires more moving parts such as pumps and fans for cooling. Finally the operational duty cycle can affect the expected battery replacement interval which impacts the total cost of ownership of the system. Different battery storage technologies have different cycle life capabilities and limitations and the properly selected technology will have to balance \$/kWh cost, cycle life, energy density, and power delivery capabilities. An overview of these three major cost categories is outlined in the following table.

<i>Cost Type</i>	<i>Description</i>
Installation	<ul style="list-style-type: none"> • Equipment purchase (battery, PCS) • Associated equipment (switches, transformers, cable) • Communications and metering • Infrastructure (pads, trench/conduit) • Electrical construction • Measuring equipment
Scheduled Maintenance	<ul style="list-style-type: none"> • Maintenance (inspection, repairs) • Training • Spare parts
Battery Replacements	<ul style="list-style-type: none"> • Varies with duty cycle & technology • Entire Energy Storage System does not need to be replaced if/when a battery replacement is needed.

3.4 Cost-effectiveness Considerations

TBD

4. Barriers Analysis & Policy Options

4.1 Barriers Resolution

<i>Barriers Identified</i>	<i>Y/N</i>	<i>Policy Options / Comments</i>
System Need	Y	Incorporate flexibility requirements into need authorization
Cohesive Regulatory Framework	Y	Existing regulatory framework does not consider storage to be used as a generation asset or transmission asset. Recognizing that storage is unique in that it can be used as both a generation or

<i>Barriers Identified</i>	<i>Y/N</i>	<i>Policy Options / Comments</i>
		<p>transmission asset.</p> <p>Storage should also be considered in all policy initiatives for current and future system or energy needs.</p> <p>Storage should also be recognized as a valuable solution in applicable policy options and proceedings such as Resource Adequacy, Long-Term Procurement Planning and RPS.</p>
Evolving Markets	Y	Need to value flexible, fast and accurate ramping capabilities of resources that have little to no direct emissions.
Resource Adequacy Value	Y	Still needs addressed. Higher valuation for flexible resources. This barrier should be addressed in the RA Proceeding.
Cost Effectiveness Analysis	Y	. Phase 2 of R.10-12-007 will establish the cost-effectiveness methodology for this Use Case. Currently working with the Commission and interested stakeholders. Some of the benefits identified are difficult to monetize with no clear opportunities to establish a framework for realizing the benefits. Markets required for some benefits are still not developed.
Cost Recovery Policies	Y	Rate base mechanism for energy storage needs to be finalized.
Cost Transparency & Price Signals	Y	Absent appropriate rate design no driver for installation.
Commercial Operating Experience	Y	Storage facilities are in operation today around the country. However, storage performing the specific applications as outlined in this Use Case in the state of California are still limited.
Interconnection Processes	Y	Simplify interconnection process for distributed resources.
Issues with RFO design and offer evaluation process	Y	Develop a more comprehensive design & evaluation RFP/RFO process to consider storage.

<i>Barriers Identified</i>	<i>Y/N</i>	<i>Policy Options / Comments</i>
Operational flexibility requirements unclear	Y	More demand side and distributed resources penetrating the system.
Value of operational flexibility unclear	Y	Need to the systems needs for flexibility and ramping under the 33% RPS framework.
Value of portfolio/procurement flexibility undefined	Y	Consider portfolio approach to procurement. Incorporate the solution into Long-Term Procurement Process and Resource Adequacy.

4.2 Other Considerations

N/A

5. Real World Examples

5.1 Ohio Smart Grid CES Demonstration Project ²

AEP Ohio is currently conducting a CES (Community Energy Storage) demonstration project in Columbus, Ohio, which is part of the larger federally funded AEP Ohio gridSMART Demonstration Project. The CES project will install 80 S&C 25-kW/25-kWh CES units along a distribution feeder serving 1,742 customers with a peak load of 6.3 MVA. The CES units will cover approximately 20% of customers on this circuit. The aggregated capacity of these 80 units is 2 MW and 2 MWh. All 80 units will be controlled by one CES control hub, acting as a virtual substation battery. The prototype CES units were under construction in June 2010. The first 20 units are scheduled to be installed in April 2011. The remaining 60 units were scheduled to be installed in October 2011. Monitoring of these systems will continue through December 2013.

5.2 Detroit Edison CES Project

Detroit Edison (DTE) is conducting a CES (Community Energy Storage) demonstration as part of its Advanced Implementation of A123's Community Energy Storage Systems for Grid Support project. The project is funded in part by the Energy Storage Systems Program of the U.S. Department of Energy. DTE's CES project will install twenty 25 kW / 50 kWh CES units along a residential distribution feeder in Northville near Detroit, Mich. The aggregated capacity of these 20 units will be 500 kW and 1 MWh. The 20 units will be controlled by DTE's Distributed Resources System Operations Center. A123 Systems will be providing CES units to the project comprised of their own batteries along with S&C's inverter and power electronics enclosure. The CES units are expected to be installed and tested between mid-2011

² Advanced Energy's Community Energy Storage Report dated January 14th, 2011

and mid-2013. A second phase of testing incorporating used plug-in electric vehicle (PEV) batteries, provided by Chrysler, will be conducted between mid-2013 and mid-2014.³

5.3 PG&E Projects

PG&E is currently demonstrating variable energy resource (VER) integration combined with distribution grid support at two sodium-sulfur (NAS) battery installations in California. A 2 MW, 12 MWh installation was recently commissioned in Vaca Dixon and will be used for combined PV integration and grid support. A 4 MW, 24 MWh installation is under construction in San Jose and will be used for combined VER integration and grid support.

5.4 Outstanding Issues

<i>Description</i>	<i>Source</i>
Accepted/vetted benefits calculation	CPUC, EPRI

5.5 Contact/Reference Materials

(TBD)

6. Conclusion and Recommendations

Is ES commercially ready to meet this use?

Yes

Is ES operationally viable for this use?

Yes

What are the non-conventional benefits of storage in this use?

1. Supply contributes with expected lower emissions.
2. Modularity/Incremental build: Energy Storage is modular in nature so that the utility only builds what they need and has the option to add more capacity if need be.
3. Siting: Can be sited in or near load centers.
- 4 Timing: Can be sited & built very quickly. Permitting process in minimal compared to a conventional peaker plant.
5. Transportability: Storage can be moved if it is determined that another location is ideal.
6. Optionality: Solve for multiple grid challenges with one solution. Part of a comprehensive risk reduction strategy for procurement.

Can these benefits be monetized through existing mechanisms?

Not currently.

If not, how should they be valued?

Could be valued against what the current/conventional solution is.

Is ES cost-effective for this use?

TBD

What are the most important barriers preventing or slowing deployment of ES in this use?

- Inability to monetize non-conventional benefits.
- Regulatory framework.
- Utilities' inability to properly evaluate energy storage via current RFO/RFP processes.

What policy options should be pursued to address the identified barriers?

1. Allow for a rate recovery mechanism.
2. Allow for Storage to seriously be considered through utility RFO/RFP processes.
3. Standard model for evaluating energy storage benefits.

Should procurement target or other policies to encourage ES deployment be considered for this use?

TBD